

# Complementarity of Process and Substance

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To my son Christoph  
 (1975-2004)

## Abstract

Process Philosophy endeavours to replace the classical ontology of substances by a process ontology centered on notions of changes and transitions. We argue, that the substantial and processual approach are mutually complementary. Here, complementarity is to be understood in the sense of a “Generalized Quantum Theory”, which is not restricted to physical phenomena. From this point of view, restricting oneself to either substance or process ontology would be as ill-advised as exclusively relying on position or momentum observables in physics. A new view on Zeno’s paradox lends itself. The meaning of an “internal energy observable”, complementary to inner time, and its relationship to “akategorial states” of the human mind will also be discussed.

## 1 Introduction

It is very difficult, if not impossible, to imagine a motion simultaneously both as a unified process and as a sequence of intermediate positions. According to a well known paradox of Zeno the Eleatic, a flying arrow seems to freeze in its motion when attention is focussed to its momentary position at any

given instant of time, noticing that it never occupies more space than given by its length.

The Eleate Parmenides contests the reality of all kinds of motion and change, reducing them to the status of mere illusions. For Plato, ideas are essentially characterized by not being subject to temporality and change, and they are the only worthy objects of pure philosophical contemplation.

In sharp contrast hereto, motion and change are central notions in the thinking of Aristotle. However, he remains indebted to Plato insofar as he understands motion exclusively from its incipient and final states, whereas the precise way in which the transition between these states is achieved is not *described*.

On the other hand, the presocratic philosopher Heraclite from Ephesos attributes reality only to the flow of motion, pushing states of rest down to a kingdom of semblance and illusion.

The question of the ontological status of time and change, for which Heraclite and Plato mark antipodal positions has ever since been a principal subject of European philosophy. It is not possible at this place to give an oversight, however sketchy, of the positions which are possible and have been adopted on this matter. It is certainly fair to say, that positions closer to Parmenides or Plato have been advocated more frequently and more influentially. The Aristotelian point of view is just one particularly prominent example for this.

More recently, the antagonism between the Parmenidean and Heraclitean position has again become an explicit subject of philosophical thought under the headings "*Substance Ontology*" versus "*Process Ontology*". The so-called *Process Philosophy* [1] criticizes an alleged one-sided preference for the substantial point of view and calls for a stronger emphasis on processual elements in ontology.

Process Philosophy usually and with a good deal of justification refers to A.N. Whitehead [2] as to one of their founding fathers. Indeed, Whitehead's philosophy is centered around notions of change, becoming and evolution.

In this study, we shall try to demonstrate that the difficulty, which becomes apparent in Zeno's paradox has its origin in a complementary relationship of the substantial and the processual points of view.

*Complementarity* as we mean it here has been introduced by Niels Bohr as a notion of quantum physics. Quantum observables like position and momentum (or velocity) are called *complementary*, if it is impossible to ascribe sharp values of arbitrary precision simultaneously to both of them. Already Bohr himself repeatedly pointed out that complementarity is a very general structure in the mutual relationship of different notions or approaches,

which should apply and be relevant far beyond the realm of physics.

Elsewhere [3] we proposed a formal framework, called "*Weak Quantum Theory*", which might also be denoted as "*Generalized Quantum Theory*". *In spite of its name, Generalized Quantum Theory is not a physical theory but a theory of systems in a very general sense. It provides a wide and flexible framework within which it is possible to talk about complementarity (and entanglement) in a well defined and not merely metaphorical way and predict their existence far beyond the range of phenomena accessible to a description in terms of physics.*

Generalized Quantum Theory shares with ordinary quantum theory the fundamental notions of "system", "state" and "observable". The structure of Generalized Quantum Theory should be realized whenever observations have an essential and inevitable influence on the state of a system. This is clearly true in an exemplary way for the human mind as seen from the inner perspective of self observation. *This is the application of Generalized Quantum Theory which we primarily have in mind in this study.* We shall relate the incompatibility of substantial and processual approaches to a complementarity of certain mental observables of time and transition .

In more detail, we shall proceed in the following way:

In section 2 we give a simplified description of Generalized Quantum Theory in order to provide the necessary background to follow our subsequent arguments. The significance of Generalized Quantum Theory is illustrated by mentioning some of its applications, which have been worked out elsewhere [3],[5],[6].

Section 3 elaborates on the notion of observables in Generalized Quantum Theory *in particular pertaining to the human mind*. A comparison with Alexius Meinong's theory of objects ("Gegenstandslehre") may be helpful to emancipate oneself from an unjustified narrow preconception prejudiced by the notion of observables in physics. In the spirit of Meinong, *intentionality* and *perspectivity* are emphasized as essential features of observables, whose creation or identification will be described as a genuine creative act of the human mind. Also essential is the notion of *partitioning*, i.e. a separation of the totality of the world into different parts by suitable observables. The "*epistemic split*" into observer and an observed object is the first and most fundamental example underlying every act of cognition.

Section 4 deals with psychic time observables and their relationship to physical time and to time complementary observables. This second class of observables should be closely related to notions of process philosophy. We also talk about a possible resolution of Zeno's paradox and give an explanation for the finite duration of the psychological "now".

Section 5 is directly devoted to the complementarity of substance and process. Both ways of description will turn out to be indispensable. Doggedly sticking to one way only would be as ill advised as if an physicist would insist in using only position or momentum observables but not both.

Section 6 is an appendix in which a short story of Jorge Luis Borges is quoted to demonstrate that an exaggeration of the process philosophical stand point will lead into absurdities. On the other hand, we point out again how deeply the human mind as seen from an internal perspective differs from a classical physical system and that in many cases notions of process philosophy seem to provide a more adequate description.

## 2 Generalized Quantum Theory

*Generalized Quantum Theory* [3] [4] is not a physical theory but a general theory of systems which could also be called *non commuting system theory*. It arose from ordinary quantum theory in algebraic form by simplification and weakening of its axioms, leaving out everything which is specific for the world of physics. The remaining structure is still rich enough to incorporate and predict phenomena like complementarity and entanglement in a much wider framework but still in a formally well defined sense.

The basic notions of *system*, *state* and *observable* are taken over from ordinary quantum theory.

- A *system*  $\Sigma$  is any part of reality in its most general sense, which can, at least in principle, be separated from the rest of the world and can be made an object of investigation. A system in *Generalized Quantum Theory* may be very different from a system in *Physics*, it may for instance, consist of an individual human mind as seen from an internal perspective of self observation. Such systems will be our main concern in the following sections. Another example of a *Generalized Quantum system* would be formed by the mental contents of a group of researchers investigating the *Elizabethan English drama*.
- A system has the capacity to reside in several *states*  $z$ . Epistemically, a state describes the degree of knowledge an observer possesses about the system. In contrast to ordinary quantum theory, it is not assumed that the set  $\mathcal{Z}$  of all states of a system can be described by the structure of a linear Hilbert space.
- Every observable  $A$  corresponds to a feature of the system, which can be investigated in a (more or less) meaningful way. Let  $\mathcal{A}$  denote the

totality of all observables of a system. *The most important feature of observables in Generalized Quantum Theory, shared with ordinary quantum theory, is the fact that the application of observables will in general change the state of a system. Indeed, observables can be identified with functions on the states. This means: Every observable  $A$  associates to every state  $z$  another state  $A(z)$ . As functions on states, observables  $A$  and  $B$  can be concatenated by applying first  $B$  then  $A$  on the states  $z$ . The composite observable  $AB$  is then defined by  $AB(z) = A(B(z))$ . Two observables  $A, B$  are called *compatible* if they commute with each other, i.e. if  $AB = BA$ . Otherwise, if  $AB \neq BA$ , they are called *incompatible* or *complementary*. In ordinary physical quantum theory, observables can also be added and multiplied with complex numbers, and to every observable  $A$  there exists a conjugate observable  $A^*$ , such that the set  $\mathcal{A}$  of all observables is endowed with a rich so-called *C\*-structure*. In Generalized Quantum Theory only the multiplication described above is defined, and the totality of observables only has the much simpler structure of a so-called *semigroup*.*

*"Measurement" is another fundamental notion of both Generalized and ordinary quantum theory. Measurement means that the investigation belonging to an observable is really performed and that a result of the investigation is obtained. After the measurement, the state of the system will in general differ from the state before the measurement. For the examples of the individual mind and the group of Elizabethan researchers it is immediately clear that measurement and application of observables will change their states. Already in ordinary quantum theory, the process of measurement and the obtainment of a result are not completely describable as a dynamical process of physics, although, of course, they are related to a physical interaction between a measurement device and the physical system under investigation. Rather "measurement" and "reduction of state" are primary and largely irreducible notions of physical quantum theory. This is also true for Generalized Quantum Theory, which in its most general form does not even contain a notion of dynamics.*

Generalized Quantum Theory is defined by a set of axioms. *For readers with a background in formal mathematics we here list the most important ones. Other readers may skip them in reading.*

- Associated to every observable  $A$  there is a set  $\text{spec}A$ , called *spectrum* of  $A$ .  $\text{spec}A$  is just the set of all possible outcomes of the investigation ("measurement") pertaining to the observable  $A$ . In *Generalized Quantum Theory*,  $\text{spec}A$  will not necessarily be a set of numbers, because the outcome of an observation may be of qualitative rather than quantitative nature.
- *Propositions* are special observables  $P$ , which are reproduced under multiplication:  $PP = P$ , and whose spectra  $\text{spec}P$  can only contain the two elements „yes“ and „no“. They simply correspond to yes-no questions about the system  $\Sigma$ . To every proposition  $P$  there is an associated negated proposition  $\bar{P}$ , which is compatible with  $P$  in the sense defined above. For compatible  $P_1$  and  $P_2$  there exist a *conjunction*  $P_1 \wedge P_2 = P_1 P_2$  and a *disjunction*  $P_1 \vee P_2 = \overline{\bar{P}_1 \wedge \bar{P}_2}$ . The laws of Boolean logic are valid for compatible propositions.
- If  $z$  is a state and if for the proposition  $P$  the answer "yes" is obtained in the state  $z$ , then  $P(z) = PP(z) = P(P(z))$  is a state, for which  $P$  yields the answer "yes" with certainty. This is a reflection of the active, constructive character of measurement in quantum theory as both verification and preparation.
- The following axiom generalizes the spectral property of observables in ordinary quantum theory and allows to reduce all observables to propositions: To every observable  $A$  and to every element  $\alpha$  in  $\text{spec}A$  there is an associated proposition  $A_\alpha$ , which just means that  $\alpha$  is the result of a measurement of  $A$ . Then

$$A_\alpha A_\beta = A_\beta A_\alpha = 0 \text{ for } \alpha \neq \beta, \quad AA_\alpha = A_\alpha A, \quad \bigvee_{\alpha \in \text{spec}A} A_\alpha = \mathbb{1},$$

where 0 and  $\mathbb{1}$  are trivial propositions which are never or always true respectively. The observables  $A$  and  $B$  are compatible if and only if  $A_\alpha$  and  $B_\beta$  are compatible for all  $\alpha \in \text{spec}A$  and  $\beta \in \text{spec}B$ .

The concepts of *complementarity* and *entanglement* are meaningful and important in Generalized Quantum Theory as well. For complementary observables  $A$  and  $B$ , the order in which they are measured is decisive. In Generalized Quantum Theory as well as in ordinary quantum theory it is in general not possible to find a state  $z$  for which both  $A$  and  $B$  have a well determined value.

*Entanglement is a special case of complementarity. It can arise, if global observables pertaining to the system as a whole are complementary to local observable pertaining to parts of the system. In an entangled state, for instance in a state, in which a global observable has a well defined value, the values of local observables are in general not determined. However, there are typical interactionless entanglement correlations between the results of measurements for local observables belonging to different parts of the system.*

We explicitly stress that Generalized Quantum Theory, at least in its minimal version presented here, does not associate quantified probabilities to the different outcomes of the measurement of an observable  $A$ . This is closely related to the absence of any Hilbert space structure for the set of states  $\mathcal{Z}$ .

Time is not a fundamental notion of Generalized Quantum Theory, *and even if time observables exist, there is not necessarily any concept of dynamics or Hamiltonian*. Planck's constant  $h$ , which in ordinary quantum theory measures the degree of non commutativity, has no privileged place in Generalized Quantum Theory.

Generalized Quantum Theory is a universal and very flexible framework theory. It should prove its value in situations, in which, just like in ordinary quantum theory, measurement has an inevitable influence on the state of a system. *This study mainly deals with systems containing human minds, which are particularly clear examples for such a situation.*

Let us mention here some *other applications, of Generalized Quantum Theory* which have been proposed and worked out in more or less detail:

- Countertransference in mentally closely bound groups of persons [3]. The frequently reported phenomenon, that members of such a group experience mental contents or emotions which do not seem to belong to themselves but to other members may be described as an effect of entanglement correlation between mental observables of different group members. The relevant global observables are related to the degree of mental concord or other collective observables of mood and disposition.
- H. Walach e.a [7] propose to explain the illusive efficiency of homeopathy, which is otherwise hard grasp, by entanglement correlations.
- So-called synchronistic phenomena in the sense of W. Pauli and C.G. Jung admit an interpretation as entanglement correlations. [8], [11], [9]

- Generalized Quantum Theory as such is timeless. In the study [6] a scenario is described how, starting from internal time as a form of existence as a conscious being, time observables can be identified and their relationship to physical time can be clarified. In section 5 we shall be more explicit on this matter.
- Bistable stimuli like Necker's cube can be perceived in two different ways. Confronted to such a bistable stimulus, conception of a person will switch back and forth more or less regularly between the two different interpretations. H. Atmanspacher, Th. Filk and H. Römer [5] give a quantitative description of the switching process in terms of Generalized Quantum Theory. In particular, a relation between three different time constants of perception physiology is derived in agreement with experiment.
- In sociological systems, entanglement correlations are conceivable between attitudes and actions of different individuals [12].
- *P. beim Graben and H. Atmanspacher [13] have demonstrated that the structure of Generalized Quantum Theory may even be realized in stochastic dynamical systems of classical mechanics.*

### 3 Observables

We already mentioned that observables are associated to any feature of a system which can be investigated in whatever way. In Generalized Quantum Theory, a system can be quite different from a system in physics and much more multifarious. Correspondingly, also observables will be more complex and manifold. They are the subject of this section.

We already saw that observables are reducible to propositions or, more precisely, to questions attributed to propositions. As a sentence in human language, propositions will in general contain both nouns and verbs. Already for this reason it would be premature to identify observables with nouns or concepts as might be suggested by the example of physical observables like position or momentum.

We shall in particular dwell on three characteristic features of observables:



- a) *Intentionality*, i.e. directedness on something else, as already evident from their relationship to questions
- b) *Perspectivity*, because questions are posed from the perspective of those who ask them
- c) *Structuring activity*, because it is by the kind and horizon of his questions that the investigator prestructures the object of his investigation and in a way even constitutes it.

To a)

We are *mainly interested in observables as features of the human mind as seen from a position of self observation*. To avoid the danger of an erroneously narrow notion of observables, a look on the theory of objects ("*Gegenstandslehre*") [14] of the philosopher *Alexius Meinong* (1853-1920) may be helpful. For Meinong, *object* ("*Gegenstand*") is everything, which can somehow be given to the human mind, and he endeavors to list objects as completely as possible. As a disciple of Franz Brentano he strongly emphasizes the intentionality of these objects of the human mind, their directedness onto something. Parallel to the four principal kind of activity of the human mind: imagining, thinking, feeling and desiring, he decides between four classes of objects ("*Gegenstände*")

- *Objects (in the narrower sense)*: conceptions, directed onto "things"
- *Objectiva*: directed onto judgements or propositions
- *Dignitativa*: directed on values like "good", "true" or "beautiful"
- *Desiderativa*: desires, obligations, purposes

The first class of objects by no means comprises only conceptions of really existing things. On the contrary, an unbiased look at the human mind reveals that such conceptions are rather an exception. In this context Meinong talks about a "prejudice in favor of the real" ("*Vorurteil zu Gunsten des Wirklichen*") prevailing in the traditional philosophy, which is primarily devoted to cognition.

Within the four classes Meinong differentiates between *simple objects* and *composite objects*, composed of objects of the same or different classes. Objects of the last three classes are always composite. Composedness cannot be continued to infinity but ends up with objects of the first class after a finite number of steps.

We are now able to locate the position of observables of the human mind in Meinong's classification: In Generalized Quantum Theory they correspond to *objectiva*, which in turn may be composed of objects of all four classes.

To b)

Already the name of "observables" tells that they are related to an observer, whom one should imagine to be endowed with at least some minimal degree of consciousness. It depends on the horizon and the perspective of the observer what he is able and willing to observe, in other words, what are the observables of an observed system. Perspective and horizon of the observer will change, not the least as a result of his observations. Thereby the totality of observables assumes a genuinely dynamic character. Both in ordinary and in Generalized Quantum Theory, systems only arise as observed systems. However, in ref [6] we showed a way to conceive the whole of the world as a limiting system of a process of repeated enlargement of systems. In physics, this is successfully done in *Quantum Cosmology*. The "universe" of Generalized Quantum Theory should be much more comprehensive, rather like C:G: Jung's *unus mundus* [11], [8], which is organized by archetypes and neutral with respect to a distinction between mind and matter.

To c)

We already mentioned that setting up and identifying observables must be recognized as a crucial constitutive mental act. This is true in particular for the *partitioning* of a system  $\Sigma$  into subsystems  $\Sigma_i$ , which may be performed in many different ways under various points of view. By this act of partitioning, the subsystems are not just registered but, together with the total system literally constituted.

G. Mahler [15] repeatedly and vigorously pointed out the key importance of the act of partitioning into subsystems.

Partitioning is done by means of *partition observables* whose different values allow to decide between different subsystems. In physics, the position observable  $Q$  is the fundamental partition observable identifying subsystems by their different positions. Indeed, it seems to be justified to say that the realm of physics is coincident with the range of applicability of partitioning with respect to different positions. From this perspective, the physical world really looks like the world of *res extensae*.

If, with all due care, the whole of the world, the *unus mundus*, is conceived as a system, then the first and all-decisive partition, prior to any act

of cognition, is the *epistemic split* into observer and observed. Without such a split it is impossible to talk about knowledge to be obtained by someone about something. The precise position of this split may be movable, for instance in the transition from the external perspective to the internal perspective of self observation, but the split itself can never be avoided.

One definitely has to expect that different partition observables leading to different positions of the epistemic split may be complementary to each other. In such situations, results of cognition obtained from different cognitive perspectives will be incompatible. This incompatibility would not be due to the simple fact that different perspectives cannot be assumed at the same time, rather the results obtained from one perspective would lose their secured validity in a different perspective.

There might even exist observables of the *unus mundus* in the sense described under point b), which are complementary to every epistemic split. They would correspond to features of the "universe" which are inaccessible from any perspective opposing an observer to something he observes.

In physics, the epistemic split arises under the name of the *Heisenberg cut* between the measuring instrument and the measured physical object. It can be investigated to some extent by physical methods in the theory of the measurement process in quantum physics, where a composite system consisting of a measuring device and an object to be measured is analyzed. The measuring instrument and the measured object are driven into an entangled state, and the usefulness of the measuring instrument has its origin precisely in the ensuing entanglement correlations. The transition to the entangled state is purely deterministic, and the typical stochastic and indeterministic features of quantum theory only emerge after applying the Heisenberg cut, reducing the composed system to the measuring instrument and interpreting the measured value as a statement about the measured object.

*Interestingly enough, in physics, there is a symmetry between measurement apparatus and measured object in the following sense: Reduction of the state of the composite system to the measured object results in the same probability distribution as reduction to the measurement device.*

One may wonder, whether such a symmetry between observer and observed holds true also in Generalized Quantum Theory. A symmetry of this kind would secure the adequacy of the findings obtained by the observer and would correspond to a tight correlation between interior and exterior world. What is observed, is mirrored in the observer, the observed mirrors the observer, and both are part of the same universe.

## 4 Substance and Process Observables

Generalized Quantum Theory as such does not contain any reference to time. Also C.G. Jung's *unus mundus* is entirely timeless. On the other hand, every conscious individual is intimately bound to temporality as a mode of its existence. Employing a distinction introduced by McTaggart [16], individual subjective time is an A-Time, which is directed from past into future and in which presence is distinguished by a particular and unmistakable feature of "now". By this, subjective A-Time differs from physical B-Time which is of poorer structure, undirected and without a distinguished "now". Rather, all points of physical time are equivalent marks on a homogenous scale. There can be no doubt, that the subjective times of different individuals are closely correlated with the subjective times of other individuals and with systems in the external world like planets or clocks.

H. Primas [10] and the author [6] proposed different but in many respects also similar scenarios, how time could emerge from a primordially timeless *unus mundus*. Here we shall briefly sketch the proposal of ref. [6], which contains the following steps:

First step: after an epistemic split of the *unus mundus*, subsystems  $\Sigma_i$  can be identified, which correspond to conscious individuals.

Second step: In these subsystems  $\Sigma_i$ , subjective time observables  $T_i$  can be identified, whose values are connected by strong entanglement correlations with observables of other subsystems. (The mechanism according to which certain observables qualify themselves as time observables is analogous to the emergence of a time observable via the timeless Wheeler- de Witt equation [17] of quantum cosmology.) The subjective time observables  $T_i$  are of A-type. So, in this scenario, the origin of time is located in the subjective A-Times of conscious individuals.

Third step: By strong entanglement correlations, the subjective A-Times  $T_i$  are not only related to each others but also to observables  $T_I$  of clocklike physical systems  $\Sigma_I$ .

Fourth step: By a long and complicated process with many intermediate stages, time will be more and more transported into the outside world and related to observables of physical systems chosen in such a way that entanglement correlations become as strict as possible. The physical time eventually emerging in this procedure has lost its character as an A-Time and is left as a B-Time of simpler structure.

Irrespectively of any concrete scenario for the emergence of time, we shall only assume in the sequel that there are subsystems  $\Sigma_i$ , which can be identified with conscious individuals and that among the *mental* observables

of  $\Sigma_i$  there are observables  $T_i$  of the type of an A-Time. Although it is not absolutely necessary, one would tend to expect  $T_i T_j = T_j T_i$  for different individuals.

Now, considering one such subsystem  $\Sigma_i$  we can divide all observables, in particular those pertaining to  $\Sigma_i$ , into two different classes:

A) *Time compatible observables*  $R$  with  $RT_i = T_i R$ . Such observables commute with the time observable  $T_i$ . They are either direct functions of  $T_i$  or have no relation to time whatsoever. In this case, a measurement of  $R$  and an attribution of a value of time will in no way influence or disturb each other. Examples of time compatible observables are the position observable  $Q$  or its internal representation in  $\Sigma_i$  and observables of shape and colour, because spacial localizations and shapes as well as colours are completely unrelated to time.

Time compatible observables describe timeless features of a system like the sum of angles in a triangle or Platonic ideas. We propose to identify such observables with observables referring to notions of an ontology of substances as mentioned in the Introduction.

Henceforth we shall call such observables *Substance Observables*. In the sense of section 3, Substance Observables are to be associated to nominal sentences (in question form).

B) *Time complementary observables*  $S$  with  $S \neq T_i S$ . Attributing a value to  $S$  and attributing a precise mark of time are incompatible in the sense of complementarity. A typical example of a time complementary observable in quantum physics is given by the energy observable. A location in time and a precise value of the energy cannot be achieved together with arbitrary precision. Quite generally, observables will be time complementary, if they are related to processes or changes with time.

From now on, we shall call time complementary observables *Process Observables*. They correspond to notions in an ontology of processes and are generically related to verbal sentences (in question form).

Even if a time variable  $T_i$  and the concepts of Substance and Process Observables are defined, this does not imply the existence of dynamics in a system of Generalized Quantum Theory. The notion of process applies to observables and is more general than the notion of a dynamical equation regulating the time development of states of a system. In particular, we cannot in general expect the existence of an observable generating all time changes of the states.

One should expect that Process Observables are complementary to Substance Observables, because the notions of endurance and change should be incompatible in a generalized quantum system. From a formal point of view,

there is of cause a possibility of observables commuting with both  $T_i$  and all Process Observables, but such observables, if they existed at all would have nothing to do with the distinction between substance and process and can be disregarded for our purposes.

The complementarity of Substance Observables and Process Observables in *Generalized Quantum Theory* leads to a simple resolution of Zeno's paradox: The position of a moving body at any given time is described by a Substance Observable like the position observable  $Q$ , whereas the motion itself is described by a Process Observable. The complementarity of them explains, why the quantity of motion and the intermediate position cannot ascribed together with arbitrary precision. In the same way, in ordinary quantum mechanics, the notion of the orbit of a moving body, which assigns a position to every point  $t$  of time loses its precise meaning.

Quite generally, for every change in the inner or outer world, one should expect a complementarity between Substance Observables for intermediate states and Process Observables for describing the phenomenon of transition itself.

In quantum mechanics, the *energy observable is privileged by being maximally complementary* to physical time. In fact, the energy observables functions as the generator of changes with time.

At the beginning of this section and in ref [6] we introduced internal subjective time observables  $T_i$  belonging to conscious individuals  $\Sigma_i$  and contended that the physical time variable  $T$  arises from the observables  $T_i$  by operationalization, externalization, purification and structural simplification. It is now natural to wonder whether for the individual  $\Sigma_i$  there exists a *privileged Process Observable*  $E_i$  of energy type, whose relationship to  $T_i$  is analogous to the relationship between the physical time  $T$  and the physical energy observable  $E$ . Indeed, the notion of physical energy developed slowly from an intuitive notion of energy as the result of a long process of purification and idealization. This intuitive energy notion should help to arrive at an idea about the character of such individual energy observables  $E_i$ . Intuitively, the notion of energy *originally contained* an element of will and of the ability to bring about changes. The notion of physical energy is both sharper and narrower: it is the generator of changes in time but it is void of any element of will or desire.

In any case, it seems to be natural to assume the existence of a *special Process Observable*  $E_i$  of energy type for the system  $\Sigma_i$ . Hoping not to give rise to misunderstandings, we tentatively call this observable *mental energy*. There will be a complementarity relation  $T_i E_i \neq E_i T_i$ .

This complementarity of internal time and mental energy provides an

easy explanation for an important result of the physiology of perception: The subjective "now" has a finite duration of the order of magnitude of 0.03 seconds. Below this threshold of temporal distance, events cannot be arranged in their correct temporal order. Because of the complementarity of physical time and physical energy, an ever more precise localization in time is possible only at the expense of an ever increasing physical energy. Likewise, localization in subjective time should be restricted by a limited supply of mental energy.

## 5 Complementarity of Substance and Process

It should have become clear by now that, in particular for proper description of the activities of the human mind, both notions of substance and process are indispensable. The problem is to incorporate both into a coherent model of thought. A remarkable attempt in this direction has been made by Atmanspacher and Fach [19], who implement ideas of William James in a the framework of a formal model. Let us quote a passage from James' "Principles of Psychology" dealing with the "stream of thoughts".

*When the rate [of change of the subjective state] is slow we are aware of the object of our thought in a comparatively restful and stable way. When rapid, we are aware of the passage, a relation, a transition from it or between it and something else. . . . Let us call the resting-places the "substantive parts" and the places of flight the "transitive parts" of the stream of thoughts. It then appears that the main end of our thinking is at all times the attainment of some other subjective part than the one from which we have just been dislodged. And we may say that the main use of the transitive parts is to lead from one substantive conclusion to another.*

*Now it is very difficult, introspectively, to see the transitive parts as what they really are. If they are but flights to a conclusion, stopping them to look at them before the conclusion is reached is really annihilating them. Whilst if we wait till the conclusion be reached, it so exceeds them in vigour and stability that it quite eclipses and swallows them up in a its glare. Let anyone try to cut a thought across in the middle and get a look at its section, and he will see how difficult the introspective observation of the transitive act is. . . . The results of this introspective difficulty are baleful. If to hold fast and observe the transitive parts of the thought's stream be so hard, the great blunder to which all schools are liable must be the failure to register them, and the undue emphasizing of the more substantive parts of the stream.*

Atmanspacher and Fach model James "stream of thoughts" by a Dynamic System. The mental state  $z$  is a point in a manifold of high dimensionality. The motion of the state  $z$  is driven by a potential, a function  $V$ , which describes mental dispositions and modes of functioning.

The dynamics of mental activity is assumed to be governed by a Dynamic System, i.e. a classical ordinary differential equation of the form

$$\frac{dz(t)}{dt} = \nabla V(z(t)) + \dots$$

whose solution  $z(t)$ , determines the mental state at time  $t$ .

Particular importance must be attributed to *equilibrium states*  $z_0$ , in which the system can reside for an arbitrarily long span of time. They are characterized by the condition  $\nabla V(z_0) = 0$ . These equilibrium states may be divided into *stable* and *unstable equilibrium states*. After a little deviation from a stable equilibrium state  $z_s$ , the state of the system will remain in the vicinity of  $z_s$  whereas after a small deviation from an unstable equilibrium state  $z_i$  the state of the system will migrate far away from  $z_i$ . Atmanspacher and Fach propose to identify the stable equilibrium states with the "substantive parts" of William James' "stream of thoughts", whereas the unstable equilibrium states are identified with the "transitive parts". These latter states are called "*akategorial states*" by Atmanspacher and Fach. Generic states are neither substantive nor akategorial but even more unstable than unstable equilibrium states.

It is suggestive but in no way cogent to identify the "mental states" of Atmanspacher and Fach with states of the brain. In this study, we focus on the human mind as seen from an internal perspective; the relationship between brain and mind is not topical.

As self observation will inevitably change the state of the human mind, a generalized quantum theoretical formalism seems to lend itself as the appropriate framework of description.

Our approach and the approach of Atmanspacher and Fach need not be in conflict with each other, both of them should rather be considered as attempts to cast a view on the human mind from different perspectives.

In the spirit of Generalized Quantum Theory, it appears natural to start out from the distinction between Substance Observables compatible with the inner time  $T_i$  and Process Observables complementary to  $T_i$  in a system  $\Sigma_i$  describing a conscious individual.

Substance Observables correspond to contents of the conscious human mind which are timeless in the sense that any localization in time is irrelevant



for them. Process Observables are related to contents which resist and escape from localization in time and are incompatible with it. The importance of such observables for the human mind is evident: already consciousness itself is experienced rather as a stream or flow than as an ensemble of time localizable parts. "Mental energy" as described above is another important example of a Process Observable of the human mind.

*Substance* and *Process States* of the human mind can be defined in the following way: Quite generally, an *eigenstate*  $z$  of an observable  $A$  is defined as a state  $z$ , in which it is possible to ascribe with certainty to  $A$  precisely one value in the set of its possible values given by the spectrum of  $A$ . (In the notation of section 2 this can be formalized as  $A_\alpha(z) = z$  for an  $\alpha$  in  $\text{spec}A$ .)

Now, *Substance States* are simply eigenstates of Substance Observables and *Process States* are eigenstates of Process Observables.

Substance states admit an additional localization in time, but this is in general irrelevant as, for example, in the statement: "This is a Square and it is twelve o'clock". Process States resist localization in time, and if it is attempted nevertheless, this will change the state.

The complementarity between Substance and Process Observables is crucial for our approach to the human mind in terms of a Generalized Quantum Theory. As described above, it explains the finite extension of the psychological "now" and gives a natural resolution of Zeno's paradox. For introspection, complementarity in the sense that one imagination may annihilate another one is an every days's experience.

Already for the reasons given by William James, it is harder to describe a Process State than to experience it. Process States resist the prevailing ontology of substances. Introspectively, a Process State will escape if one tries to get hold of it by means of Substance Observables.

Atmanspacher and Fach [19] devote a lot of care to a more precise description of Process States, which they call *akategorial states*.

Good examples for such states are:

1. Memory states, in which a process in the past is memorized as a whole
2. „Flow“ states, in which a person is so deeply submerged in an activity that time seems to disappear
3. Meditative states of pure consciousness. Atmanspacher and Fach characterize them by the following properties:
  - Pure consciousness of universal unity

- Absence of any localizability in space and time
- Feeling of ultimate reality
- Feeling of unification of opposites and of peace and harmony
- Difficulty of conceptual description

In our generalized quantum theoretical approach, these meditative states are plausible candidates for eigenstates of the mental energy. In ordinary quantum physics, the eigenstates of the time complementary energy observable are the so-called *stationary states*, time independent states resisting any temporal localization. As already mentioned, mental energy also contains an element of will and desire, and it should have eigenstates, which are not only non localizable in time, but for which also will has come to rest and no change in time is desired.

*In any case, we believe that we have demonstrated that Generalized Quantum Theory is a very wide and flexible scheme, which, applied to systems like  $\Sigma_i$  provides a conceptual framework, from which views can be cast on the human mind from a new and possibly interesting perspective. Complementarity is predicted as a general feature and expected to hold inevitably for Substance and Process Observables both of which are indispensable for a complete and satisfactory description of the system. Moreover, the resolution of Zeno's paradox and the finite duration of the subjective "now" are rather surprising consequences of the general scheme of Generalized Quantum Theory. A more detailed and in some parts perhaps even quantitative analysis of such systems would require a concrete model for the state space  $\mathcal{Z}_i$  and for the set  $\mathcal{A}_i$  of observables as functions on  $\mathcal{Z}_i$ . A complete description of this kind seems to be out of reach for a long time to come. Still, we hope to come back later to a more detailed quantum like description of human mind and consciousness.*

## 6 Appendix: Tlön

Process philosophy emphasizes the importance of dynamic process oriented notions describing motions and changes. Referring to authorities like Alfred North Whitehead [2] it criticizes an allegedly exaggerated weight put on timeless notions related to enduring substances or entities in European Philosophy, which are blamed to hamper a proper understanding of phenomena of utmost importance like renewal, innovation and creativity. In our terminology, process philosophy calls for a turn away from a one-sided

usage of Substance Observables and for more attention to Process observables. It may be an exciting and instructive exercise to try to get along without Substance Observables as far as possible and to discard notions of time and substance.

Reflections on time and the attempt to demonstrate its illusionary character are favored subjects of the learned Argentine writer Jorge Luis Borges (1899-1986). In his short story „*Tlön, Uqbar, Orbis Tertius*“ [18] he describes in a wonderfully subtle, free and playful way a Utopian planet *Tlön*, whose inhabitants do not have any notions of substances.

Living in a world which is organized in accordance with process philosophy and does not know about underlying enduring substances, the inhabitants of *Tlön* have no substantives in their languages. As a further natural consequence, their philosophical views are strictly idealistic, Borges says Berkelian. (Indeed, reductionist materialism as we know it is distinguished by a pronounced substance ontology.) Borges describes the *Tlönians*, who are obviously completely free of the "prejudice in favour of the real" scorned by Meinong, in the following way:

*Hume declared for all time that while Berkeley's arguments admit not the slightest refutation, they inspire not the slightest conviction. That pronouncement is entirely true with respect to earth, entirely false with respect to Tlön. The nations of that planet are, congenitally, idealistic. Their languages and those things derived from their language -religion, literature, metaphysics- presuppose idealism. For the people of Tlön, the world is not an amalgam of objects in space; it is a heterogeneous series of independent acts -the world is successive, temporal, but not spacial.*

About the languages of *Tlön*:

*There are no nouns in the conjectural Ursprache of Tlön, from which its "present day" languages and dialects derive: There are impersonal verbs, modified by monosyllabic suffixes (or prefixes) functioning as adverbs. For example, there is no noun that corresponds to our word "moon", but there is a verb which in English would be "to moonate" or to "enmoon". "The moon rose above the river" is "hlör u fang axaxaxas mlö", or, as Xul Solar succinctly translates "Upwards behind the onstreaming it mooned"*

*That principle applies to the languages of the southern hemisphere. In the northern hemisphere (about whose Ursprache Volume Eleven contains very little information), the primary unit is not the verb but the monosyllabic adjective. Nouns are formed by stringing together adjectives. One does not say "moon"; one says "aerial-bright above dark-round" or "soft- amberish-celestial" or any other string...*

*There are famous poems composed of a single enormous word, this word*

*is a "poetic object" created by the poet. The fact that no one believes in the reality expressed by these nouns means, paradoxically, that there is no limit in their number.*

At this place, we should annotate that in many human languages, for instance in Japanese, a special class of verbs is reserved to what are adjectives in European languages. From this point of view, the difference between the languages of the northern and southern hemisphere looks less radical in comparison to the shared absence of nouns.

A few lines later:

*Space is not conceived as having duration in time. The perception of a cloud of smoke on the horizon and then the countryside on fire and then the half-extinguished cigarette that produced the scorched earth is considered an example of the association of ideas.*

The lack of understanding of the Tlönians for enduring substances, goes so far, that things quite common for us look scandalous for them:

*Of all the doctrines of Tlön, none has caused more uproar than materialism. Some thinkers have formulated this philosophy (generally with less clarity than zeal) as though putting forth a paradox. In order to make this inconceivable thesis more easily understood, an eleventh-century heresiarch conceived the sophism of the nine copper coins, a paradox as scandalously famous on Tlön as the Eleatic aporiae to ourselves. There are many versions of that "specious argument", with varying numbers of coins and discoveries; the following is the most common:*

*"On Tuesday, X is walking along a deserted road and loses nine copper coins. On Thursday, Y finds four coins in the road, their luster somewhat dimmed by Wednesday's rain. On Friday, Z discovers three coins in the road. Friday morning X finds two coins on the veranda of his house."*

*From this story the heresiarch wished to deduce the reality -i.e., the continuity in time- of those nine recovered coins. "It is absurd", he said, "to imagine that four of the coins did not exist from Tuesday to Thursday, three from Tuesday to Friday afternoon, two from Tuesday to Friday morning. It is logical to think that they in fact did exist -albeit in some secret way that we are forbidden to understand- at every moment of those three periods of time."*

*The language of Tlön resisted formulating this paradox; most people did not understand it.*

Such a scandalous paradox must be abolished :

*They explained that "equality" is one thing and "identity" another, and they formulated a sort of reductio ad absurdum -the hypothetical case of nine men who on nine successive nights experience a sharp pain. Would it*

*not be absurd, they asked, to pretend that the men had suffered one and the same pain?*

At length and in a very elucidating way, Borges dwells on the philosophical systems of Tlön. The incapability of the Tlönians for any notions of substances exhibits itself in the phenomenon of *hrönir*<sup>1</sup>, as Borges calls it.

*Century upon century of idealism could hardly have failed to influence reality. In the most ancient regions of Tlön one may, not infrequently, observe the duplication of lost objects: Two persons are looking for a pencil; the first person finds it, but says nothing; the second person finds a second pencil, no less real but more in keeping with his expectations. These secondary objects are called "hrönir", and they are, though awkwardly so, slightly longer. Until recently, hrönir were the coincidental offspring of distraction and forgetfulness. It is hard to believe that they have been systematically produced for only about a hundred years....A curious bit of information: hrönir of the second and third remove -hrönir derived from another hrön and hrönir derived from the hrön of a hrön- exaggerate the aberrations of the first; those of the fifth remove are almost identical; those of the ninth can be confused with those of the second; and those of the eleventh remove exhibit a purity of line that even the originals do not exhibit. The hrönir of the twelfth remove begin to degenerate....*

*Things duplicate themselves on Tlön; they also tend to grow vague or "sketchy", and to lose detail when they begin to be forgotten. The classic example is a doorway that continued to exist so long as a certain beggar frequented it, but which was lost to sight when he died. Sometimes, a few birds, a horse, have saved the ruins of an amphitheater.*

Borges' ingenious delineation of the world of Tlön suggests the following observations:

1) An exaggeration of process ontology will result in absurd consequences. Some people stipulate that everything that can be captured by stable concepts were balefully rigid and did injustice to the intimately dynamic character of the world. Proponents of such an opinion are in danger to fall victim to the paradox of the nine copper coins.

2) On the other hand, the world of the human mind and its products and fictions is similar to the world of Tlön in many respects and really ordered rather according to a process ontology. This already becomes evident from the refutation of the copper coin paradox employing the example of

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<sup>1</sup>The word "*hrönir*" seems to be a free invention of Borges with an Icelandic appeal. In Icelandic dictionaries I only found „*hrönn*“ with plural „*hrannir*“, a poetic word with the meaning "wave".

human pain as quoted above. Even more so, on the field of fashions, trends and countermovements *hrönir* will be quite common under the disguise of repeated rediscoveries. *So, in some situations, the process ontology of Tlön may be superior to the substance ontology we are used to.*

By the way, in Borges' short story, *tlön* itself is described as a product of the inventive human mind, which is about to be replaced by the yet more complex *orbis tertius*

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